(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 September 2003 (25.09.2003)

PCT

(10) International Publication Number
WO 03/079073 A1

(51) International Patent Classification[7]: G02B 6/16, B29D 11/00, C03B 37/026

(21) International Application Number: PCT/AU03/00324

(22) International Filing Date: 17 March 2003 (17.03.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

PS1134	15 March 2002 (15.03.2002)	AU
PS1136	15 March 2002 (15.03.2002)	AU

(71) Applicant *(for all designated States except US)*: **THE UNIVERSITY OF SYDNEY** [AU/AU]; Business Liaison Office, John Woolley Building A20, Cnr Manning Road & Western Avenue, Sydney, NSW 2006 (AU).

(72) **Inventors; and**

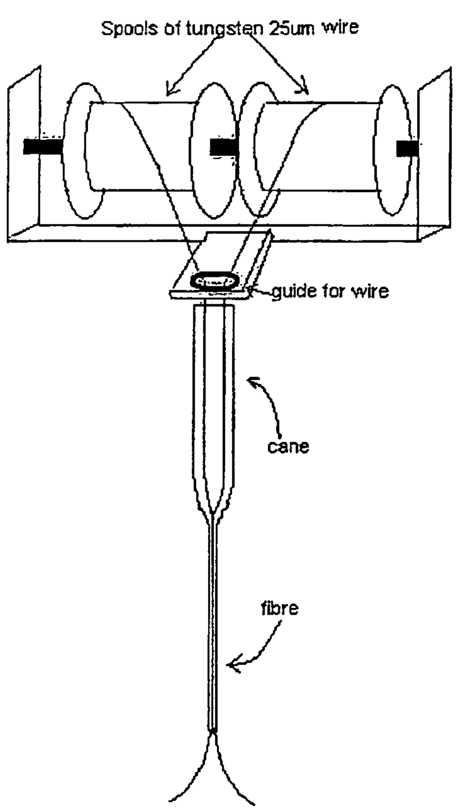
(75) **Inventors/Applicants** *(for US only)*: **LARGE, Maryanne, Candida, Jane** [AU/AU]; 25A Congham Road, West Pymble, NSW 2073 (AU). **ARGYROS, Alexander** [AU/AU]; 39 Maud Street, Fairfield Heights, NSW 2165 (AU). **VAN EIJKELENBORG, Martijn, Alexander** [NL/AU]; 193 Wilson Street, Newtown, NSW 2042 (AU). **ISSA, Nader** [AU/AU]; 193 Wilson Street, Newtown, NSW 2042 (AU). **FLEMING, Simon** [AU/AU]; 14 Goodlet Close, Lane Cove West, NSW 2066 (AU). **POLADIAN, Leon** [AU/AU]; 4/1 Charlton Way, Glebe, NSW 2037 (AU).

(74) Agent: **BALDWIN SHELSTON WATERS**; 60 Margaret Street, Sydney, NSW 2000 (AU).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,

[Continued on next page]

(54) Title: INCORPORATING INCLUSIONS IN POLYMER OPTICAL FIBRES



(57) Abstract: This invention relates to the manufacture of optical fibres, and more particularly to the manufacture of polymer optical fibres. The invention has particular application in relation to the manufacture of poled polymer optical fibres. One aspect of the present invention provides a method of forming an optical fibre, the method comprising forming one or more holes at predetermined locations in a polymeric preform, locating an elongated inclusion in said one or more holes, and subsequently drawing the preform to form a length of optical fibre including said inclusion. In one embodiment of the invention used in the manufacture of poled polymer optical fibres, the preform is a unitary polymer body and holes are formed in the polymer preform by means of drilling. Elongated inclusions in the form of metallic wire are located in the holes and the polymer body and wire are subsequently drawn to form a polymer optical fibre incorporating the wire inclusions.

WO 03/079073 A1

GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TITLE: INCORPORATING INCLUSIONS IN POLYMER OPTICAL FIBRES

FIELD OF THE INVENTION

This invention relates to the manufacture of optical fibres, and more particularly to the manufacture of polymer optical fibres.

The invention has particular application in relation to the manufacture of poled polymer optical fibres. It should be noted however that the invention is not limited to this particular field of use.

BACKGROUND OF THE INVENTION

Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

There are many applications where it is necessary or desirable for an optical fibre to be formed from a combination of two or more materials. For example, "poled" optical fibres comprising a glass body and a metallic wire inclusion are an active area of research. Their main application is in allowing the application of an electric field to the optical fibre in order to achieve an electro-optic effect. This also has the result of increasing the nonlinear optical response of the optical fibre. In glass fibres this is used to produce 'permanent' (ie. long term) effects, however, transient effects caused by the application of an electric field may also be useful for applications such as switching.

There are a number of known methods for manufacturing poled optical fibres. In one method, wires are mechanically inserted into the fibre after drawing the fibre. Other methods of inserting wires include drawing liquid metal into pre-existing holes in fibres using capillary action. However, the known techniques for producing inclusions in optical fibres have a number of shortcomings. For example, it is difficult and/or uneconomic to produce relatively long continuous lengths of optical fibres incorporating such inclusions.

It is therefore an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

SUMMARY OF THE INVENTION

A first aspect of the present invention provides a method of forming a polymer optical fibre, said method comprising forming one or more holes at predetermined locations in a polymeric preform, locating an elongated inclusion in said one or more holes, and subsequently drawing said preform to form a length of polymer optical fibre including said inclusion.

Unless the context clearly requires otherwise, throughout the description and the claims, the words 'comprise', 'comprising', and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

A second aspect of the present invention provides a method of forming a polymer optical fibre, said method comprising forming one or more holes at predetermined locations in a polymeric preform, inserting relatively low melting point metal into said one or more hole(s), and subsequently drawing said preform to form a length of polymer optical fibre including said metal.

A third aspect of the present invention provides a method of forming a polymer optical fibre, said method comprising forming one or more holes at predetermined locations in a polymeric preform, inserting a liquid material in said one or more hole(s), and subsequently drawing said preform to form a length of polymer optical fibre including said liquid material.

In one preferred embodiment, said liquid material is photo-curable. In this embodiment, the liquid material can be photo-cured to a solid after the drawing of the polymer preform.

A fourth aspect of the present invention provides a method of forming a polymer optical fibre, said method comprising forming a hole at a predetermined location in a polymeric preform, locating an elongated inclusion in said hole, filling the remaining volume of the hole with a photo-curable liquid, drawing said preform to form a length of optical fibre including said inclusion, and curing said photo-curable liquid so that the inclusion is integrated with the polymer.

A fifth aspect of the present invention provides a method of forming an optical fibre, said method comprising forming a fibre core, and subsequently casting a second material around said core to form the optical fibre.

BRIEF DESCRIPTION OF THE DRAWINGS

The various aspects of the present invention will now be described in further detail, by way of example only, and with reference to the accompanying drawings in which:

Fig. 1 is an illustration of a polymer preform design used in the manufacture of polymer optical fibre according to the present invention;

Fig. 2 is a schematic illustration of a primary oven used in the manufacture of polymer optical fibres in which a polymer preform is drawn into a cane;

Fig. 3 is a schematic illustration of a secondary draw process in which a polymer cane is drawn into a length of polymer optical fibre;

Fig. 4 is a schematic illustration of a spooling arrangement for the introduction of wire inclusions into the optical fibre during the drawing process; and

Fig. 5 is an end view of a polymer optical fibre incorporating a pair of electrically conductive wires manufactured according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the method according to the first aspect of the present invention, one or more holes are formed at predetermined locations in a preform formed from an optically suitable polymeric material such as polymethylmethacrylate. Preferably the preform is a unitary polymer body. The hole(s) may be formed in the polymer preform by a number of techniques, including drilling or casting. Typically the hole(s) are round, although alternative cross-sections are possible. The hole(s) extends through the preform in the direction in which the preform is to be drawn. An elongated inclusion of another material is located in the hole(s), the material being determined so as to provide desired properties in the resulting optical fibre. In one preferred embodiment the elongated inclusion takes the form of metallic wire. The polymer preform is then subjected to a drawing process to form a length of optical fibre including the inclusion.

In one embodiment , the polymer preform is drawn into an optical fibre in a two-stage drawing process. The preform is drawn to an intermediate stage, known as cane, and then into a fibre in a second drawing process. The second drawing process of cane to fibre may require some preparation steps, such as sleeving the cane to increase its external diameter or annealing so as to remove residual stresses. In the

case of poled fibres, the wire inclusions which form the electrodes are preferably introduced into the polymer body at the cane stage. If the inclusion is fixed at one end and free at the other, it can then be spooled into the fibre during the drawing of the preform. This method can be employed to include wires or fibres of another material that has a higher processing temperature than the polymer. Such inclusions may include glass fibre for example, or a doped material that could not be drawn with the fibre because of incompatible rheologies. If care is taken to optimise the conditions it is possible to reduce the air gap surrounding the inclusion to a negligible amount and obtain a sufficiently close fit between the polymer and the inclusion.

This technique has been successfully demonstrated for incorporating wire into a microstructured polymer fibre. In this case, a polymer preform of diameter 12.5 mm and length 150 mm was drilled with a centrally located axially extending hole of diameter 2 mm. A length of tungsten wire of diameter 25μm was fed through the hole and secured at one end of the preform. The preform was then drawn at a temperature of approximately 175°C, a draw speed of around 6 metres per minute, and a feed rate of approximately 4 mm per minute. This resulted in a fibre in excess of 25 metres in length and with a diameter as low as 100 microns. This occurred without any fracture in the tungsten wire.

In another example, an array of holes was drilled into an annealed 65 mm long, 80 mm diameter polymethylmethacrylate (PMMA) preform. The pattern of holes that was drilled into the preform is illustrated in Fig. 1 and included a centrally located hexagonal array of 1.2 mm diameter holes with a centre-to-centre spacing of 1.5 mm. These holes formed the microstructure of the resulting optical fibre. Two 10 mm diameter holes were placed either side of the central array, 14 mm from the centre so as to allow for the introduction of wire electrodes into the polymer body during the drawing process.

The drawing of the polymer preform into a length of optical fibre occurred in a two-stage process. A primary oven consisting of a metal cylinder in which the preform was suspended, is shown schematically in Fig. 2. The preform was hung near the top of the cylinder by a pair of crossed Teflon rods. The top and bottom of the metal cylinder were covered.

The preform was drawn to a cane by a slow heating process in which the temperature was gradually increased to 210°C over a period of approximately 6 hours. This temperatures is well above the glass transition temperature of PMMA, which is ~115°C.

The preform dropped slowly under its own weight. The covering on the top of the metal cylinder was removed when the temperature was increased to 190°C after about 3 hours to ensure that the preform did not deform and break away from the support rods. The bottom of the cylinder remained covered until the preform has dropped to the level of the second ring of air holes.

The neck-down region of the dropped preform was cut off, as well as the bottom, and several pieces of cane with diameters suitable for drawing into fibre were obtained.

It was at this stage that tungsten wire was threaded through the two larger holes on either side of the central array. Tungsten was chosen as an electrode material due to its properties of high strength, high melting point and resistivity to oxidation. The tungsten wire was 25μm in diameter and supplied in spools of 500m lengths. . The two large holes in the cane were of approximately 1 mm diameter, enabling the tungsten wires to be threaded through the holes.

The secondary drawing process is illustrated in Fig. 3 and involved a second oven in which the cane was heated to temperatures of about 210-230°C. Heating was via impingement heating using hot nitrogen entering the oven by a circular array of holes, to ensure even diameter in the resulting fibre. This formed the 'hot-zone', which is the area where the temperature is greatest and necking occurs. A pre-heat zone formed by the incorporation of a glass cylinder on top of the oven, which is necessary so that the preform can heat up gradually and thus uniformly.

A feed motor controlled the rate at which the cane entered the oven. The diameter of the final fibre depends on the rate at which the cane is fed into the oven and the rate at which fibre is pulled out via the capstan. Typical values of the feed and draw rates are 2 mm/min and 3 m/min respectively. The diameter was measured by a laser gauge. The secondary draw process was computer controlled and allowed for the fibre diameter to be controlled by a feedback loop between the laser gauge and capstan speed.

Fig. 4 illustrates a spooling apparatus used to facilitate the drawing of electrodes into the fibre. The spools are free to rotate on a shaft that is fixed with respect to the device. Initially the wires were taped to the bottom of the cane, which fixed them sufficiently that they did not recede into the fibre during drawing. Fig. 5 depicts the resulting optical fibre incorporating a pair of tungsten wires located on opposing sides of a centrally located microstructure. Advantageously, long continuous lengths of polymer optical fibre incorporating wire inclusions could be produced in this way.

In the second aspect of the invention, relatively low melting point metals are inserted into a polymer preform prior to drawing. For example, by using a low melting point metal such as indium or gallium it is possible to produce preform in which the polymer and metal can be drawn together. One or more holes are formed at predetermined locations in a polymeric preform. Preferably the preform is a unitary polymer body. The hole(s) may be formed in the polymer preform by a number of techniques, including drilling and casting. The hole(s) extend through the preform in the direction in which the preform is to be drawn. The metallic inclusion may be incorporated into the polymer preform by a number of methods such as casting or injection into a suitable cavity. When the preform is heated to its drawing temperature, the metal inclusion either melts or becomes sufficiently ductile such that it can be drawn compatibly with the polymer to form a continuous length of optical fibre incorporating the inclusion.

In the third aspect of the invention, a second material in the form of a liquid is included in a polymer preform, which is then drawn to form the optical fibre. One or more holes are formed at predetermined locations in a preform. The preform is formed from an optically suitable polymeric material, such as for example polymethylmethacrylate. Preferably the preform is a unitary polymer body. The hole(s) may be formed in the polymer preform by a number of techniques, including drilling or casting. Typically the hole(s) are round, although alternative cross-sections are possible. The hole(s) extends through the preform in the direction in which the preform is to be drawn. The liquid material is preferably photo-curable so that it may be cured to a solid after the drawing of the fibre. Such liquids may include, for example, dyes, liquid crystals, electro-chromic materials, magneto-optic materials,

metallic nano-particles, chiral materials, or other polymeric materials that can be photo-cured subsequent to drawing. One example of a photo-curable polymeric material which has potential application in this invention for the production of relatively low loss optical fibres is Inorganic Polymer Glass™ (IPG™), a highly stable, inorganic polymer material developed by RPO Pty Ltd of Sydney, Australia.

Is to be noted that to ensure suitable results, care must be taken in the choice of liquid so that it is immiscible in the polymer and has a boiling point higher than the drawing temperature. Furthermore, depending upon the compatibility of the second material with the polymer from which the preform is made there may be a need to use an interface material so as to assist with the adhesion and/or wetting of the two materials. This interface material may be added to the hole surface in the preform prior to the addition of the photo curable material.

Advantageously, the technique of incorporating a liquid into a cavity in a polymer preform and then subsequently drawing the preform enables longer continuous lengths of optical fibre to be produced. Furthermore, in a microstructured fibre it is possible to ensure that the liquid is accurately placed in certain, predetermined cavities and not in others.

Furthermore, this technique affords improved thermal and mechanical stability in the resulting fibre. It also avoids the problems of relaxation of the host polymer material into a different shape and the diffusion of the differing materials.

A further advantage arising from the second material being introduced into the polymer preform in a liquid phase is that if the second material is poled whilst in a liquid phase, either by the application of electrical or magnetic fields, and the second material is subsequently cured, the orientations formed in the second material will remain stable.

In the fourth aspect of the invention, an elongated inclusion is located within a hole in a polymeric preform. The remaining void of the hole is filled with the photo-curable liquid and then the preform is drawn. The fibre is then subjected to a photo-curing step so as to set the liquid material to a solid. This permits inclusions such as glass cores or wires which can be completely surrounded by polymer material so that there are no voids in the optical fibre.

In the fifth aspect of the invention, after a fibre core has been drawn an outer layer of material, incorporating one or more inclusions, is cast around the fibre core. In the case of a microstructured fibre, the drawn fibre comprises the core and microstructure. It is to be noted that any polymeric material applied after the core of the fibre has been drawn must be applied in such a way that the mechanical or optical properties of the fibre are not compromised. For example, the wrong choice of polymer system may result in the applied polymer solution being soluble in the polymer used in the fibre. If this were the case then the applied polymer would then tend to dissolve the fibre around which it was applied. For this reason, it is preferable that a photo-curable system be applied, so that the applied polymer is polymerised without damage to the fibre, as occurs in the application of the polymer "jacket" in the normal drawing process. A "jacket" of this kind can be used to include wires and other materials. A potential limitation of this process is that because of the need to apply it after the fibre has been drawn, the distance of the inclusion from the core may be limited by the diameter of fibre that can be reliably drawn.

There are a number of advantages and potential applications for polymer optical fibres which incorporate inclusions of a second material. These include:

(i) By incorporating fine elongated metallic inclusions into an optical fibre it is possible to modify the refractive index characteristics of the fibre. More particularly, it is possible to design and manufacture a polymer optical fibre with a particular desired refractive index profile.

(ii) By incorporating fine elongated metallic inclusions into the optical fibre it is possible to increase the nonlinear optical behaviour of the fibre by increasing the local electric field density, although care needs to be taken to keep losses at acceptable levels.

(iii) By incorporating helical inclusions of electrically conductive material into an optical fibre magneto-optic effects can be created. The helicity of a metallic wire inclusion will cause it to act as a solenoid when an electric current is passed through it. This can then be used to create magneto-optic effects, which are essential for applications such as optical isolators. Wire coils may be made by spinning a fibre with wire inclusions, or by coiling a wire around the core of a fibre and

subsequently applying an outer jacket of material, such a photo-curable polymer.

(iv) Incorporation of materials to obtain specific effects such as low optical loss or active components. There are a number of materials that could be usefully incorporated in polymer fibres, which however cannot be drawn compatibly the polymer. For example, it may be advantageous to incorporate a low-loss glass core in a microstructured polymer fibre. This would allow the polymer to be used to obtain the hole structure of choice, while using the glass in the core to obtain low loss. The significantly higher processing temperatures for glasses mean that glass and polymers cannot normally be drawn together. More generally it may be useful to include in a polymer fibre some material that has an incompatible rheology. This might include a fibre or capillary containing an active element such as dispersed species (atomic or molecular) or an incompatible polymer.

(v) By incorporating inclusions into the polymer body in a predetermined manner, it is possible to modify the material stresses within the resulting optical fibre so as to achieve desired optical characteristics. For example, material stresses or physical deformation of the wave-guide structure can enhance desirable birefringence.

Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

CLAIMS

1. A method of forming a polymer optical fibre, said method comprising forming one or more holes at predetermined locations in a polymeric preform, locating an elongated inclusion in said one or more holes, and subsequently drawing said preform to form a length of polymer optical fibre including said inclusion.

2. The method of forming a polymer optical fibre as claimed in claim 1, wherein a plurality of holes are formed at predetermined locations in the polymeric preform.

3. The method of forming a polymer optical fibre as claimed in claim 1 or 2 wherein said hole(s) extends through the preform in the direction in which the preform is to be drawn.

4. A method of forming a polymer optical fibre, said method comprising forming one or more holes at predetermined locations in a polymeric preform, inserting a relatively low melting point metal into said one or more hole(s), and subsequently drawing said preform to form a length of polymer optical fibre including said metal.

5. The method of forming a polymer optical fibre as claimed in claim 4 wherein said low melting point metal is indium or gallium.

6. The method of forming a polymer optical fibre as claimed in claim 4 wherein the metallic inclusion is incorporated into the preform by casting.

7. The method of forming a polymer optical fibre as claimed in claim 4 wherein the metallic inclusion is incorporated into the preform by injection.

8. The method of forming a polymer optical fibre as claimed in any one of claims 1 to 7 wherein elongated metallic inclusions are incorporated into the optical fibre so as to modify the refractive index of the fibre.

9. The method of forming a polymer optical fibre as claimed in any one of claims 1 to 8 wherein elongated metallic inclusions are incorporated into the optical fibre so as to increase the nonlinear optical behaviour of the fibre by increasing the local electric field density.

10. The method of forming a polymer optical fibre as claimed in any one of claims 1 to 9 wherein the elongated metallic inclusion comprises a helically wound electrically conductive material.

11. The method of forming a polymer optical fibre as claimed in any one of claims 1 to 10 wherein said elongated inclusions act as stress inducing elements in the optical fibre to achieve desired optical characteristics.

12. A method of forming a polymer optical fibre, said method comprising forming one or more holes at predetermined locations in a polymeric preform, inserting a liquid material in said one or more hole(s), and subsequently drawing said preform to form a length of polymer optical fibre including said liquid material.

13. The method of forming a polymer optical fibre as claimed in claim 12 wherein said liquid material is photo-curable.

14. The method of forming a polymer optical fibre as claimed in claim 13 wherein said liquid material is photo-cured to a solid after the drawing of the preform.

15. The method of forming a polymer optical fibre as claimed in claim 12 wherein said liquid material is immiscible in the polymer and has a boiling point higher than the drawing temperature.

16. The method of forming a polymer optical fibre as claimed in claim 12 wherein said liquid material includes dyes, liquid crystals, electro-chromic materials, or polymeric materials that can be photo-cured subsequently to drawing.

17. A method of forming a polymer optical fibre, said method comprising forming a hole at a predetermined location in a polymeric preform, locating an elongated inclusion in said hole, filling the remaining volume of the hole with a photo-curable liquid, drawing said preform to form a length of optical fibre including said inclusion, and curing the photo-curable liquid so that the inclusion is integrated with the polymer.

18. The method of forming a polymer optical fibre as claimed in claim 17 wherein said elongated inclusion is metallic and is chosen and located in said preform so as to modify the refractive index of the resulting fibre in a predetermined manner.

19. The method of forming a polymer optical fibre as claimed in claim 17 wherein said elongated inclusion is metallic and is chosen and located in said preform so as to increase the nonlinear optical behaviour of the resulting fibre.

20. The method of forming a polymer optical fibre as claimed in claim 17 wherein said elongated inclusion is chosen and located in said preform so as to act as a stress inducing element and achieve desired optical characteristics in the resulting fibre.

21. The method of forming a polymer optical fibre as claimed in claim 17 wherein the inclusion is a metallic helical wire.

22. The method of forming a polymer optical fibre as claimed in claim 17 wherein the inclusion is a low-loss glass core.

23. A method of forming a polymer optical fibre, said method comprising forming a fibre core, and subsequently casting a second material around said core to form the optical fibre.

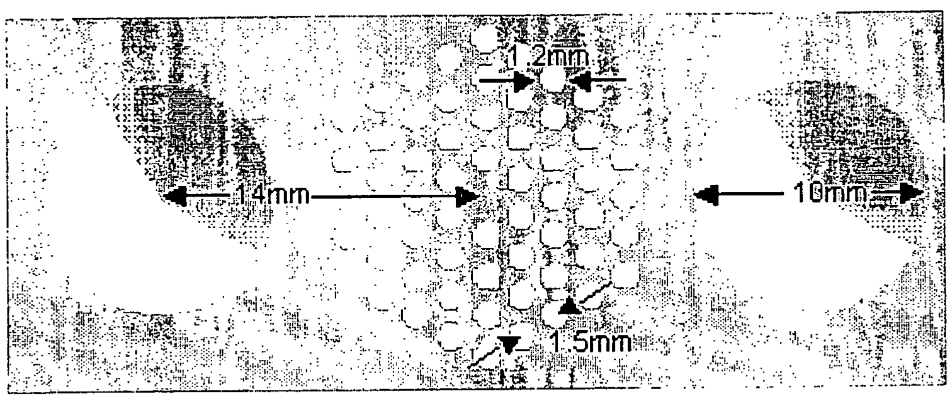


Fig. 1

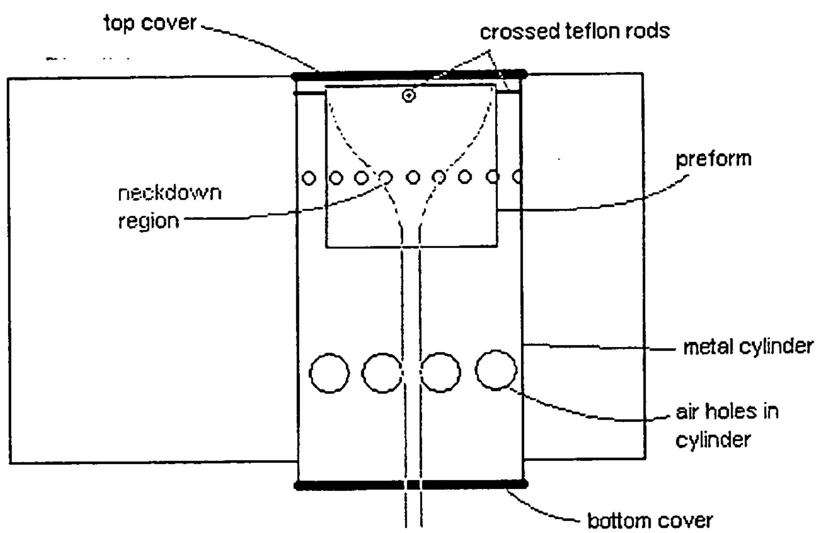

top cover
crossed teflon rods
preform
neckdown region
metal cylinder
air holes in cylinder
bottom cover

Fig. 2

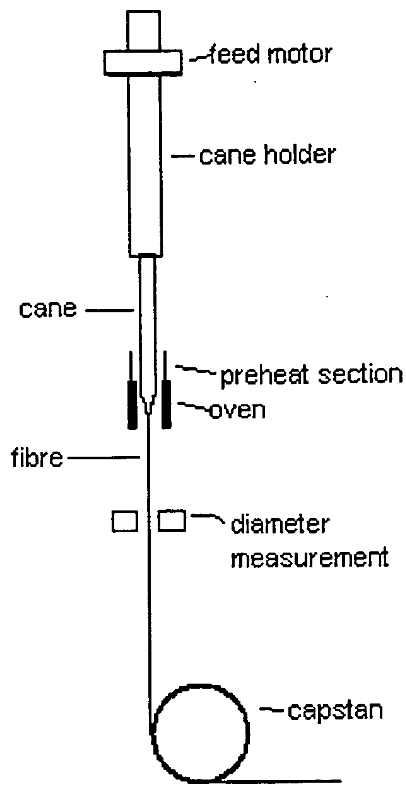

feed motor
cane holder
cane
preheat section
oven
fibre
diameter measurement
capstan

Fig. 3

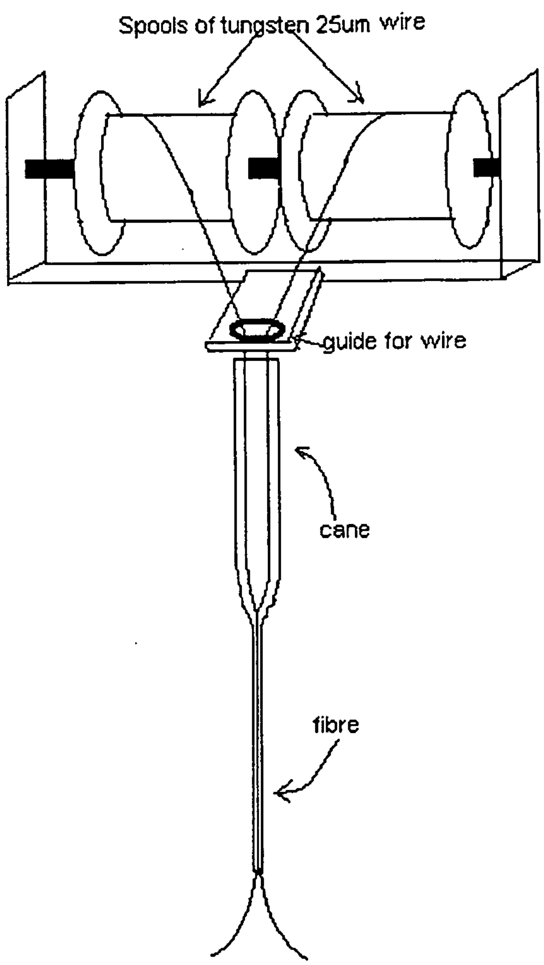


Fig. 4

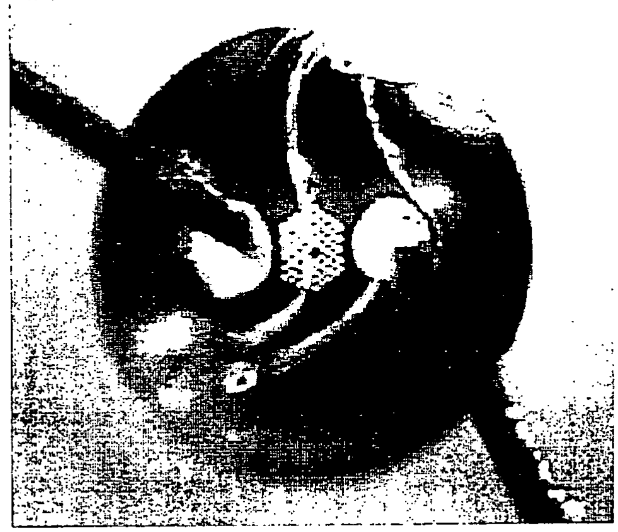


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU03/00324

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: G02B 6/16, B29D 11/00, C03B 37/026

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI: keywords [optic+; fiber?, fibre?, waveguide?; plastic, polymer+; preform?; inclusion?, insert+, wire?, metal+, poled, poling]; C03B 37/026 & keywords [optic+]

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 01/40833 A (CORNING INCORPORATED) 7 June 2001 Page 6 line 24 - page 7 line 27, page 11 lines 20-27, figures 1, 2	1-22
A	US 5167684 A (TURPIN *et al.*) 1 December 1992 Col. 4 line 18 -col. 5 line 10, figures 2b, 5, claims 2-6	1-22
A	M.A. van Eijkelenborg *et al.*, "MICROSTRUCTURED POLYMER OPTICAL FIBRE", Optics Express, vol. 9, No. 7, pages 319-327 Sec. 4 "Advantages of microstructured polymer optical fibre"	1-22

☒ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 May 2003	19 MAY 2003

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	**IRINA TALANINA** Telephone No : (02) 6283 2203

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU03/00324

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	EP 1207140 A (LUCENT TECHNOLOGIES INC) 22 May 2002 Col. 3 lines 15-49, col. 5 lines 19-26, figures 1, 2, claims 1, 4, 6, 7	1-22
P, A	WO 03/009027 A (THE UNIVERSITY OF SYDNEY) 30 January 2003 The whole document	1-22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU03/00324

Supplemental Box
(To be used when the space in any of Boxes I to VIII is not sufficient)

Continuation of Box No II:

The international application does not comply with the requirements of unity of invention because it does not relate to one invention only (or to a group of inventions so linked as to form a single general inventive concept). In assessing whether there is more than one invention claimed, a consideration has been given to those features which can be considered to be "special technical features". These are features which potentially distinguish the claimed combination of features from the prior art. Where different claims have different special technical features, they define different inventions. The International Searching Authority has found that there are two different inventions as follows:

(1) Claims 1-22 are directed to a method of forming a polymer optical fibre. It is considered that **forming one or more holes in a polymeric preform and locating an inclusion in said one or more holes** comprises a first "special technical feature".

(2) Claim 23 is directed to a method of forming a polymer optical fibre. It is considered that **forming a fibre core and subsequently casting a second material around said core** comprises a second "special technical feature".

Since the above mentioned groups of claims do not share either of the special technical features identified, a "technical relationship" between the inventions, as defined in PCT Rule 13.2, does not exist. Accordingly, the international application does not relate to one invention or to a single inventive concept, **a priori**.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU03/00324

Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos :

   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos :

   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos :

   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: **1-22**

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	200140833	AU	200112483	CA	2393000	EP	1234198
		US	6259830				
US	5167684	AU	67644/90	EP	430781	FR	2655326
EP	1207140	JP	2002220248				
WO	2003009027	AU	20016496				

END OF ANNEX